SIR-C/X-SAR RADAR STUDIES; IMPACT AND AEOLIAN FEATURES, BORKOU REGION NORTHERN CHAD. *J.F. McHone, R. Greeley, D. Blumberg*, Dept.of Geology, Arizona State University, Tempe, AZ 85287-1404 *also at Dept. of Geography, Ben-Gurion University of the Negev, Beer Sheva, Israel*

Spaceborne Radar Laboratory (SRL) multiwavelength and multipolarization images of the Borkou region in northern Chad reveal a landscape dominated by aeolian and impact processes. Steady winds in long-established patterns have cut into flat sandstones and shales to form a series of linear erosional grooves which serve as conduits for mobile sands. Dunes migrate many tens of kilometers along the grooves and, in one area, pass through the remnants of the Aorounga impact structure. Active dunes which appear distinctive on radar data with a critical incidence angle near 32° (the angle of repose for medium sands) and look directions perpendicular to the direction of sand movement provide important clues to the local Saharan sand budget.

Aorounga Astrobleme: The Aorounga multi-ring structure, centered at 19°06'N;019°15'E, is a recently confirmed impact feature [1,2]. On both optical and radar images it appears as a prominent bulls-eye pattern of concentric ring-troughs. An inner trough with a maximum diameter of about 3.5 km surrounds a central highland and, in turn, is surrounded by a second circular trench 1.5 km wide and up to 12.5 km in maximum diameter. Radar can penetrate several wavelengths of dry sand cover and, compared to optical data, can detect otherwise invisible bedrock patterns. SRL images indicate disturbed target rocks occur in an elliptical zone with a major east-west axis as wide as 19 km. Aorounga is not yet dated but must be younger than the Upper Devonian sandstones and shales in which it formed. Earlier investigators, because of its position relatively near the Tibesti Mountains and the great Emi Koussi volcano, usually attributed it to a volcanic or plutonic origin [3].

Aeolian Features: The Borkou region occupies the broad gap between the Tibesti Mountains to the northwest and the Ennedi Mountains to the southeast. Steady winds from the Libyan Desert flow though this gap for most of the year to make it one of the windiest environments of the Sahara [4]. Wintertime northwesterly wind velocities average 22 cm/sec and distinct aeolian features have developed in response. Much of the region is now a vast expanse of parallel, steep walled topographic grooves as large as 15m deep and 1.5km wide which are separated by linear ridges, or yardangs, tens of kilometers in length [5].

SRL imaged the Borkou site during three separate and nearly parallel ascending orbits, each with a different incidence angle. Two data takes were illuminated from a northerly direction and one from the south. Track lines were oriented close to the strike direction of the yardangs and resulted in strong, radar-bright returns from exposed ridge slopes oriented perpendicular to the spacecraft's emitted radar beams. Radar-dark zones between ridges result from radar shadows and from sand deposits on the valley floors.

The general region is characterized by a relatively bare surface of windswept bedrock. Unconsolidated granular materials are organized into thin sheets or into chains of regularly spaced barchanoid dunes whose spatial distribution is influenced by local upwind topography. Sand bodies advance from a northeastern source region and impinge on the sharply defined eastern margin of the yardang field. Here they accumulate as transition forms which penetrate the yardang field at points of lower elevation. Mobile sands enter the trough regions between parallel bedrock ridges and continue to migrate downwind as predominantly transverse dunes which selectively abrade and maintain the grooves as geomorphic features. At the downwind limit of the yardang field, sand bodies emerging from individual troughs transform again into crescentic barchans.

Minor variations in radar incidence angle produce marked differences in the image appearance of individual sand bodies [6,7]. Data Take 140.10 was recorded with an incidence angle of 31.9 degrees, essentially perpendicular to the angle of repose for dry medium-grained sands. This maximum surface slope is a characteristic of youthful, active dunes and not of more subtle, rounded mounds of stagnant sand. On L-HH and and, to a lesser extent, on L-HV derived images, bright radar returns mark the positions of concave avalanche slopes, steep slip faces, and undulating crest line ridges. Within the impact feature, trailing dunes have developed along the downwind slopes of the large trough ring and appear as radar-dark wind streaks. Tapering dune

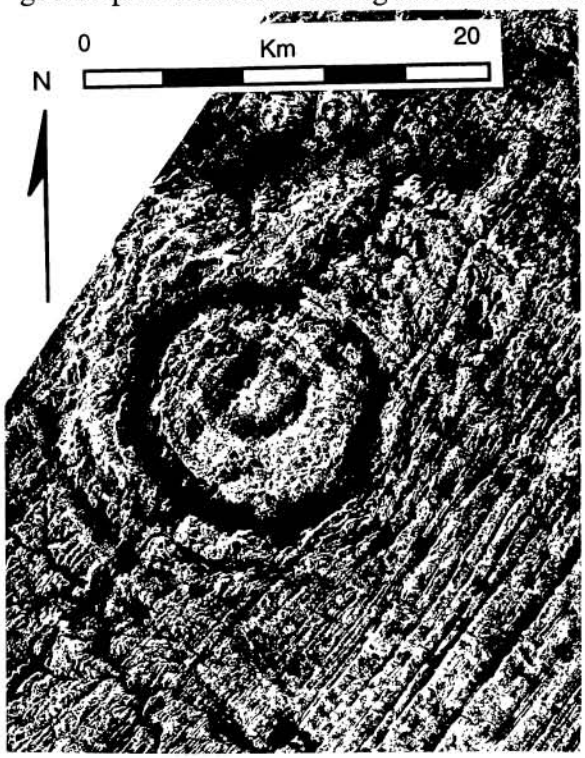
RADAR STUDIES; BORKOU, CHAD J. McHone et al.

tails with sharp , undulating ridge crests have steep concave flanks which produce bright quasi-specular radar returns. The brightest radar echoes, associated with crest lines and with steeper portions of large barchans, appear as stellated point-source patterns typical of corner reflector antenna signals in which radar energy is returned directly to its source antenna over a relatively long segment of orbit track line. Bright point-source reflectors are absent or significantly curtailed in X-band (3 cm) images in which backscatter from surface roughness, mostly sand ripples, is increased and attenuation by sediment penetration is reduced.

SRL Data Takes of Borkou with incidence angles and corresponding appearances of mobile sand bodies

Data Take	Inc.Ang.	Radar Appearance of Sand Dunes
124.00	**23.3°**	Dark bodies, little or no radar return
140.10	**1.9°**	Mostly dark, very bright spots are common
060.10	**35.6°**	Distinctly "shaded" from surface slope effects

Summary: Orbital altitude multiple frequency and polarization SRL radar data provide high resolution images of a remote and hostile, wind dominated desert environment in northern Chad. Multiple coverage with varied incidence angles permits the distinction and monitoring of active sand bodies while precise spatial data allows accurate determination of location and dimensions for geomorphic features including individual dunes, yardangs and the Aorounga impact structure.



SRL radar image of Borkou Region, Chad. Bright diagonal linears are rock ridges (yardangs) separated by wind-cut channels. The channels contain radardark sand dunes which are actively migrating to the southwest. Dark circular patterns are sand-floored annular synclines of the Aorounga impact structure.

SIR-C Data Take 140.10, L-HH
ASU Negative No. IPF-1006

References: [1] Becq-Giraudon, J.F., et al., (1992) *Comptes Rendus de l'Academie des Sciences*, Ser.2, *315* (1) 83-88. [2] Grieve, R.A.F. and A.M. Therriault, (1995) *Lunar Planet. Sci. Conf., 26th*, 515-516. [3] Roland, N.W., (1976) *Geologisches Jahrbuch*, Reihe A, *33*, 117-131. [4] Mainguet, M. and Y. Callot, (1978) *Service. de Documentation et de Cartographie Geophysiques, Edtns. Centre national de la recherche scientifique, Memoires et documents; nouv. ser., v. 18*, 184 pp. Paris. [5] Bagnold, R.A., (1933) *Geogr. Jour.*, 82, 103-129, 211-246. [6] Blom, R. and Elachi, C. (1987) *J. Geophys. Res. 92*, 7877-7889. [7] Lancaster, N.L., et al., (1992) *Remote Sens. Environ. 39* 233-238.